

## WHAT IS CLAIMED IS:

1. A frequency mixer comprising:

a first differential amplifier for amplifying a first pair of input signals(RF1, RF2)  
5 having a first frequency( $f_1$ ) to output a first differential output signal;

a second differential amplifier for amplifying a second pair of input signals  
orthogonal to the first input signals to output a second differential output signal, the  
second pair of input signals having a substantially same frequency as the first  
frequency( $f_1$ );

10 a subtracter for subtracting the second differential output signal from the first  
differential output signal to output a subtracted output signal; and

a mixer for mixing the subtracted output signal, and a first pair of drive signals  
having a second frequency( $f_2$ ) and a second pair of drive signals orthogonal to the  
first pair of drive signals and having the second frequency( $f_2$ ), wherein the mixer has  
15 a sub-harmonic double balanced mixing mode, and for outputting a pair of output  
signals orthogonal to each other, wherein at least one harmonic is cancelled from  
the output signals.

2. The frequency mixer of claim 1, wherein the second frequency ( $f_2$ ) is  
20 about half of the first frequency ( $f_1$ ).

3. The frequency mixer of claim 1, wherein the output signals belong to a  
baseband frequency.

25 4. The frequency mixer of claim 1, wherein a cancelled harmonic has a  
frequency of  $f_1 - 2f_2$ .

5. The frequency mixer of claim 1, wherein

the subtracter includes a first transformer and a second transformer;

30 the first transformer having a first polarity is inductively coupled to the first  
differential output signal of the first polarity and is connected between the first  
differential amplifier and the mixer; and

the second transformer is inductively coupled to the second differential output

signal of a second polarity that is opposite to the first polarity, and is connected between the second differential amplifier and the mixer.

6. The frequency mixer of claim 5, wherein

the first differential amplifier has a first pair of emitter-coupled transistors and a first bias current source;

each of transistors in the first pair of emitter coupled transistors has a collector that is conductively connected to a respective one of the two terminals of a first winding of the first transformer;

a center tap of the first winding of the first transformer is connected to a first voltage source;

the first pair of emitter-coupled transistors, wherein each transistor has a bases respectively receiving one input signal of the first pair input signals; and

the first bias current source is connected between a common node between the emitters of the first pair of emitter coupled transistors and a second voltage source.

7. The frequency mixer of claim 6, wherein the mixer comprises;

a first frequency multiplier connected between a first output node and a terminal of a second winding of the first transformer, switched by the first pair of drive signals,

a second frequency multiplier connected between a second output node and the terminal of the second winding of the first transformer, switched by the second pair of drive signals.

8. The frequency mixer of claim 6, wherein the first differential amplifier further comprises a pair of regeneration resistors, each regeneration resistors being connected between an emitter of each transistor and the common node between the emitters of the emitter-coupled transistors.

9. The frequency mixer of claim 7 further comprising a capacitor connected between the first output node and the second output node.

10. A frequency mixer comprising:

a first differential amplifier for amplifying a first pair of input signals having a first frequency( $f_1$ ) for outputting a first differential output signal;

a second differential amplifier for amplifying a second pair of input signals  
5 orthogonal to the first pair input signals having the first frequency ( $f_1$ ) and for outputting a second differential output signal;

a subtracter for subtracting the second differential output signal from the first differential output signal and for outputting a subtracted output signal; and

a mixer for mixing the subtracted output signal and a pair of drive signals  
10 having a second frequency( $f_2$ ) in a double balanced mixing mode for outputting a pair of output signals orthogonal to each other wherein at least one harmonic is cancelled.

11. The frequency mixer of claim 10, wherein the first and second  
15 frequencies are substantially equal.

12. The frequency mixer of claim 10, wherein the output signals have a baseband frequency.

13. The frequency mixer of claim 10, wherein the harmonic has a  
20 frequency of  $f_1 - f_2$ .

14. The frequency mixer of claim 10, wherein  
the subtracter has a first transformer and a second transformer;  
25 the first transformer is inductively coupled to the first differential output signal of a first polarity and is connected between the first differential amplifier and the mixer; and

the second transformer is inductively coupled to the second differential output signal of a second polarity that is opposite to the first polarity, and is  
30 connected between the second differential amplifier and the mixer.

15. The frequency mixer of claim 15, wherein  
the first differential amplifier has a first pair of emitter coupled transistors and  
a first bias current source;

5 the first pair of emitter coupled transistors has two collectors each connected  
to a different one of two terminals of a first winding of the first transformer,  
respectively;

a center tap of the first winding of the first transformer is connected to a first  
voltage source; and

10 each transistor in the first pair of emitter coupled transistors has a base  
respectively receiving one of the first pair input signals; and

the first bias current source is connected between a common node of the first  
pair of emitter coupled transistors and to a second voltage source.

15 16. The frequency mixer of claim 15, wherein  
the mixer has a third pair of emitter-coupled transistors and a fourth pair of  
emitter-coupled transistors,

20 each transistor of the third pair of emitter-coupled transistors has a collector  
respectively connected to a first output node and a second output node, and a base  
receiving the one of the pair of drive signals, respectively, and an emitter commonly  
connected to a terminal of a second winding of the first transformer;

25 each transistor of the fourth pair of emitter-coupled transistors has a collector  
respectively connected to the first and the second output node, a base receiving one  
of the pair of drive signals, respectively, and an emitter commonly connected to a  
terminal of a second winding of the second transformer.

17. A frequency mixer comprising:

30 a differential amplifier for amplifying a first pair of radio frequency (RF) input  
signals having a first frequency ( $f_1$ ) and for generating a first current signal at a first  
node and a second current signal at a second node;

a harmonic rejection circuit for processing a second pair of input signals  
orthogonal to the first pair of input signals and for generating a third current signal at

the first node and a fourth current signal at the second node, the second pair of input signals having a substantially same frequency as the first frequency (f1); and

a mixer for mixing the current signals applied to the first and the second node with a first pair of drive signals and a second pair of drive signals being orthogonal to each other and having a second frequency (f2), in a sub-harmonic double balanced mixing mode, adapted to output a pair of output signals orthogonal to each other, a harmonic being cancelled from the output signals.

18. The frequency mixer of claim 17, wherein the harmonics rejection circuit comprises;

a first transistor coupled to a voltage source via a first bias current source, wherein a base of the first transistor receives one signal of the second pair input signals and an emitter of the first transistor is connected to the first node;

a second bias current source connected between the first node and a ground;

a second transistor coupled to the voltage source via a third bias current source, wherein a base of the second transistor receives a remaining signal of the second pair of input signals and an emitter of the second transistor is connected to the second node; and

a fourth bias current source connected between the second node and the ground.

19. The frequency mixer of claim 18, wherein the differential amplifier has a first pair of emitter-coupled transistors and a fifth bias current source;

each transistor of the first pair of emitter-coupled transistors has a collector connected to the first and second nodes, respectively, and a base respectively receiving one of the first pair of input signals; and

the fifth bias current source is connected between a common node of the first pair of emitter-coupled transistors and a second voltage source.

20. The frequency mixer of claim 18, wherein a bias current of the fifth bias current source is about twice of a current of the first, second, third and fourth bias current sources.

21. A circuit for receiving a radio frequency signal comprising:

a first poly-phase filter for transforming a radio frequency signal having a first  
5 frequency( $f_1$ ) into two pairs of input signals orthogonal to each other;

a second poly-phase filter for transforming a local oscillator signal into a first  
and second signals groups being  $45^\circ$  out of phase with respect to each other, each  
of the signal groups having two pairs of drive signals orthogonal to each other;

a first mixer for mixing the two pairs of input signals and the two pairs of drive  
10 signals in the first signal group and for outputting a first output signal having a third  
frequency, the first mixer being operatively connected to the first and second poly-  
phase filters; and

a second mixer for mixing the two pairs of input signals and the two pairs of  
drive signals in the second signal group and for outputting a second output signal  
15 having a substantially same frequency as the third frequency, the second mixer  
being operatively connected to the first and second poly-phase filters.

22. The circuit of claim 21, wherein the first and second output signals are  
orthogonal to each other.

23. The circuit of claim 21, wherein each of the first and second mixers is  
a sub-harmonic double balanced mixer adapted to cancel harmonics.

24. The circuit of claim 23, wherein the second frequency is about half of  
25 the first frequency.

25. The circuit of claim 23, wherein the first and second output signals  
belong to a baseband frequency.

26. The circuit of claim 24, wherein one of the cancelled harmonics has a  
30 frequency of  $f_1 - 2f_2$ .

27. A circuit for receiving a radio frequency signal comprising:

a first poly-phase filter for transforming a radio frequency signal having a first frequency (f1) into two pairs of input signals, each having a different phase from other input signals;

5 a second poly-phase filter for transforming a local oscillator signal having a second frequency (f2) into two pairs of drive signals orthogonal to each other;

a first mixer for mixing the two pairs of input signals with one pair of the two pairs of drive signals, to output a first output signal having a third frequency, the first mixer being operatively coupled to the first and second poly-phase filters; and

10 a second mixer for mixing the two pairs of input signals with a remaining pair of the two pairs of drive signals, to output a second output signal having a substantially same frequency as the third frequency, the second mixer being operatively coupled to the first and second poly-phase filters.

28. The circuit of claim 27, wherein the first and second output signals are  
15 90° out of phase with respect to each other.

29. The circuit of claim 28, wherein each of the first and second mixers cancels harmonics.

20 30. The circuit of claim 28, wherein the first and second frequencies are substantially the same.

31. The circuit of claim 28, wherein the first and second output signals belong to a baseband frequency.

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32. The circuit of claim 28, wherein a cancelled harmonic has a frequency of f1-f2.

33. A method comprising:

30 transforming a radio frequency signal having a first frequency into two pairs of input signals orthogonal to each other;

providing a first and second signal groups being 45° out of phase with respect to each other, each of the signal groups having two pairs of drive signals orthogonal

to each other;

mixing the two pairs of input signals and the two pairs of drive signals of the first signal group to output a first output signal having a third frequency; and

mixing the two pairs of input signals and the two pairs of drive signals of the second signal group to output a second output signal having a substantially same frequency as the third frequency.

34. The method of claim 33, wherein the first and second output signals are 90° out of phase with respect to each other.

35. The method of claim 33, wherein the two pairs of input signals are mixed with the two pairs of drive signals of the first signal group in a first mixer, and the two pairs of input signals are mixed with the two pairs of drive signals of the second signal group in a second mixer,

in a sub-harmonic double balanced active mixing mode adapted to cancel harmonics.

36. A method comprising:  
transforming a radio frequency signal having a first frequency into two pairs of input signals orthogonal to each other;

providing two pairs of drive signals orthogonal to each other and both having a second frequency;

mixing the two pairs of input signals and one pair of the two pairs of drive signals to output a first output signal having a third frequency; and

mixing the two pairs of input signals and a remaining pair of the two pairs of drive signals to output a second output signal having a substantially same frequency as the third frequency.

37. The method of claim 36, wherein the two pairs of input signals are mixed with one of the two pairs of drive signals by a double balanced active mixing mode adapted to cancel harmonics.

38. The method of claim 37, wherein the two pairs of input signals are

mixed with the remaining of the two pairs of drive signals by the double balanced active mixing mode adapted to cancel harmonics.

39. A method comprising:

5 providing a first differential signal having a first frequency;  
providing a second differential signal orthogonal to the first differential signal,  
and having a substantially same frequency as the first frequency;  
subtracting the second differential signal from the first differential signal to  
output a subtracted signal; and  
10 mixing the subtracted signal, and a first pair of drive signals and a second pair  
of drive signals orthogonal to each other having a second frequency, in a sub-  
harmonic double balanced mixing mode, to output a pair of output signals being  
orthogonal to each other, a harmonic being cancelled from the output signals.

15 40. A method comprising:

amplifying a first pair of input signals having a first frequency to output a first  
differential signal;  
amplifying a second pair of input signals orthogonal to the first pair of input  
signals to output a second differential signal, the second pair of input signals having  
20 a substantially same frequency as the first frequency;  
subtracting the second differential signal from the first differential signal to  
output a subtracted signal; and  
mixing the subtracted signal with a pair of drive signals having a second  
frequency, in a sub-harmonic double balanced mixing mode, to output a pair of  
25 output signals orthogonal to each other, wherein a harmonic is cancelled in the  
output signals.

41. A method comprising:

30 amplifying a first pair of input signals, having a first frequency, to output first  
and second input signals;  
subtracting respectively a third and fourth current signals from a first and  
second current signals to output a first and second subtracted signals wherein a  
second pair of input signals orthogonal to the first pair of input signals have a

substantially same frequency as the first frequency; and

mixing the first and the second subtracted signals, and a first pair of drive signals and a second pair of drive signals orthogonal to each other, in a sub-harmonic double balanced mixing mode, to output a pair of output signals  
5 orthogonal to each other, wherein the first pair of drive signals and the second pair of drive signals have a second frequency.

42. A frequency mixer comprising:

a first amplifier for amplifying a first input signal having a first frequency, to  
10 output a first amplified signal;

a second amplifier for amplifying a second input signal orthogonal to the first input signal, to output a second amplified signal, the second input signal having a substantially same frequency as the first frequency;

a subtracter for subtracting the second amplified signal from the first amplified  
15 signal, and for outputting a subtracted signal; and

a mixer for mixing the subtracted signal with a drive signal having a second frequency, in sub-harmonic double balanced mixing mode, to output a output signal, a harmonic being cancelled from the output signal.

20 43. The frequency mixer of claim 42, wherein the first and second amplifiers are differential amplifiers.

44. The frequency mixer of claim 42, wherein the first and second input signals are 180° out of phase with respect to each other.

25 45. The frequency mixer of claim 44, wherein the drive signal has a first pair of drive signals and a second pair of drive signals orthogonal to each other.

46. The frequency mixer of claim 45, wherein the second frequency is  
30 about half of the first frequency.